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Citation style: Żurek Sławomir, Nita Małgorzata, Imioł Katarzyna. (2011). Krzywopłoty – Late Glacial and Holocene Mire in the Bydlin Area (Częstochowa Upland). "Bulletin of Geography. Physical Geography Series" (2011, vol. 4, iss. 1, p. 89-102), doi 10.2478/bgeo-2011-0005

Bulletin of Geography – **Physical Geography Series**
No 4/2011: 89–102

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KRZYWOPŁOTY – LATE GLACIAL AND HOLOCENE MIRE IN THE BYDLIN AREA (CZĘSTOCHOWA UPLAND)

Abstract. Macroscopic and laboratory tests of over 4-metre-thick organic deposits of Krzywopłoty profile (gyttjas and peat) allowed the authors to identify the development of the peatland as having four phases, each transition being associated with fluctuations in water level. Sediments from a depth of 3.75–0.65 m were also included in palynological testing. Seven local pollen assemblage zones show a continuous transformation in the plant landscape and surroundings of the site between the end of the Vistulian and the Holocene. Pollen data indicates a change of vegetation, from open communities of herbaceous plants and loose pine-birch communities in the Younger Dryas, then dense pine forests in the Preboreal chronozone, and finally multispecies forests in the Atlantic and Subboreal chronozones.

Key words: Holocene, mire, pollen analysis, peatland

Introduction

What led the authors to undertake research of the Krzywopłoty site (Fig. 1) was the lack of attention thus far paid to Holocene peat bogs in the area of the Silesia-Cracow Upland. A good illustration of the extent of examination of mires on the Upland is the extent of palynological studies carried out here. Until now, pollen analysis of vegetation changes during the Late Glacial and Holocene has only been documented in a few sites, namely the profiles of Jaworzno-Jęzor (Szczepanek & Stachowicz-Rybka 2004), Wolbrom (Latałowa, Nalepka 1987, Latałowa 1989) and Jezioro (Nita, Szymczyk 2010). In the late 1990s, profiles from Bąków (Mamakowa 1997) and Bronów (Granoszewski 1998) were also examined, but the full results of these investigations have yet to be published.

Studies on the Krzywopłoty mire were conducted in order to identify the stages of its development in relation to fluctuations in water level. The authors' aim was also to investigate vegetation changes in the region. This seemed interesting because the radiocarbon date obtained from the bottom part of deposits (4450 ± 70 BP, Ki-11393) suggested a young age for the mire (Woźniak, Żurek 2005). In contrast, sediments from the Subboreal chronozone do not occur in the Wolbrom profile (Latałowa 1989), while in the Jezioro site located a bit further away, there are no sediments from the Subatlantic chronozone (Nita, Szymczyk 2010).

Preliminary studies on the Krzywopłoty mire from 2003 were discussed at the scientific conference "Diversity and transformation of the natural and cultural environment on the Krakow-Częstochowa Upland," and published in Volume 3 Supplement (Woźniak and Żurek 2005).

Study site

Krzywopłoty is located in the southern part of the Częstochowa Upland mezoregion (Kondracki 2000), in the microregion of Brama Wolbromska (Czeppe 1972). It is located 1 km NW of Bydlin village and 9 km west from Wolbrom. The Krzywopłoty peatland is located in a depression of about 400 × 200 m (Fig. 2) and it is currently drained by ditches to the Tarnówka valley, a right-bank tributary of the Biała Przemsza river. The depression is surrounded by Krzywopłoty village to the west and Zawadka village to the east. From the north, west and south it is surrounded by hills of heights: 396.8 m, 410 m and 368 m a.s.l. The reasonably flat surface of the peatland slopes gently from 349 m a.s.l. in the north-west to 345 m a.s.l. in the south-east.

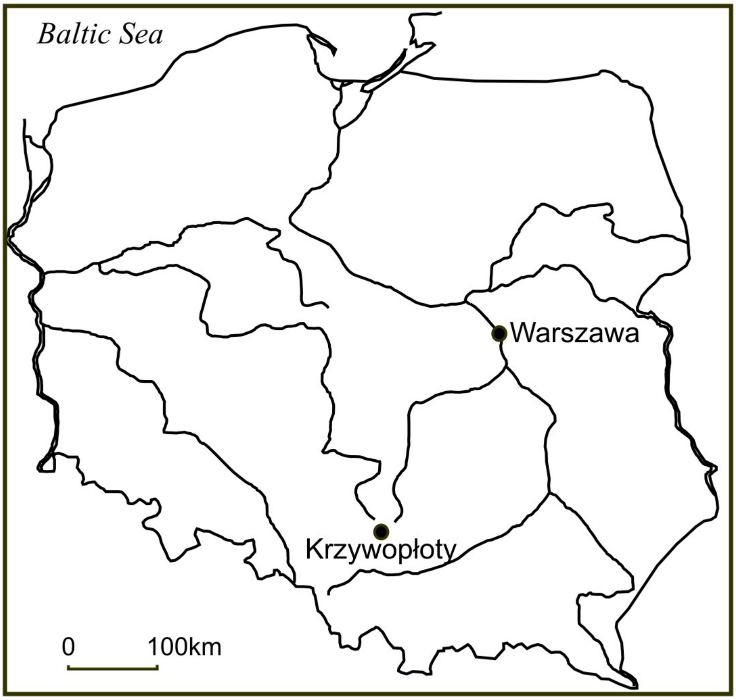

Fig. 1. Location of the Krzywopłoty peatland

This area was described by Pulina (2001) as a system of depressions in the Tarnówka valley, where karstic sources of the river start at a height of 367 m a.s.l in the region of Czarny Las. The genesis of the depression is associated with karst processes and he calls them "paleopolja". He mentions only that during flooding some of them (e.g. Krzywopłoty) are filled with water to form reservoirs. Pulina associates the formation of the cavities with the Tertiary age. The Krzywopłoty area was also mentioned by M. Kuc (1959 p. 447), who describes the presence of *Sphagnum compactum* Lam. & DC. here. The Krzywopłoty peatland covers an area of about 10 ha, and is overgrown with reed rush to a height of about 2 m. It is drained by irregular grid ditches and water drains into the Tarnówka river, 500 m north from the mouth of the Stoki tributary. The drainage has resulted in mucking of the top 10-cm layer of peat and has contributed to the invasion of reeds.

Drilling (K2) was performed in the central part of the depression (Fig. 2), in a high clump of birches, 5 m from a ditch filled with water.

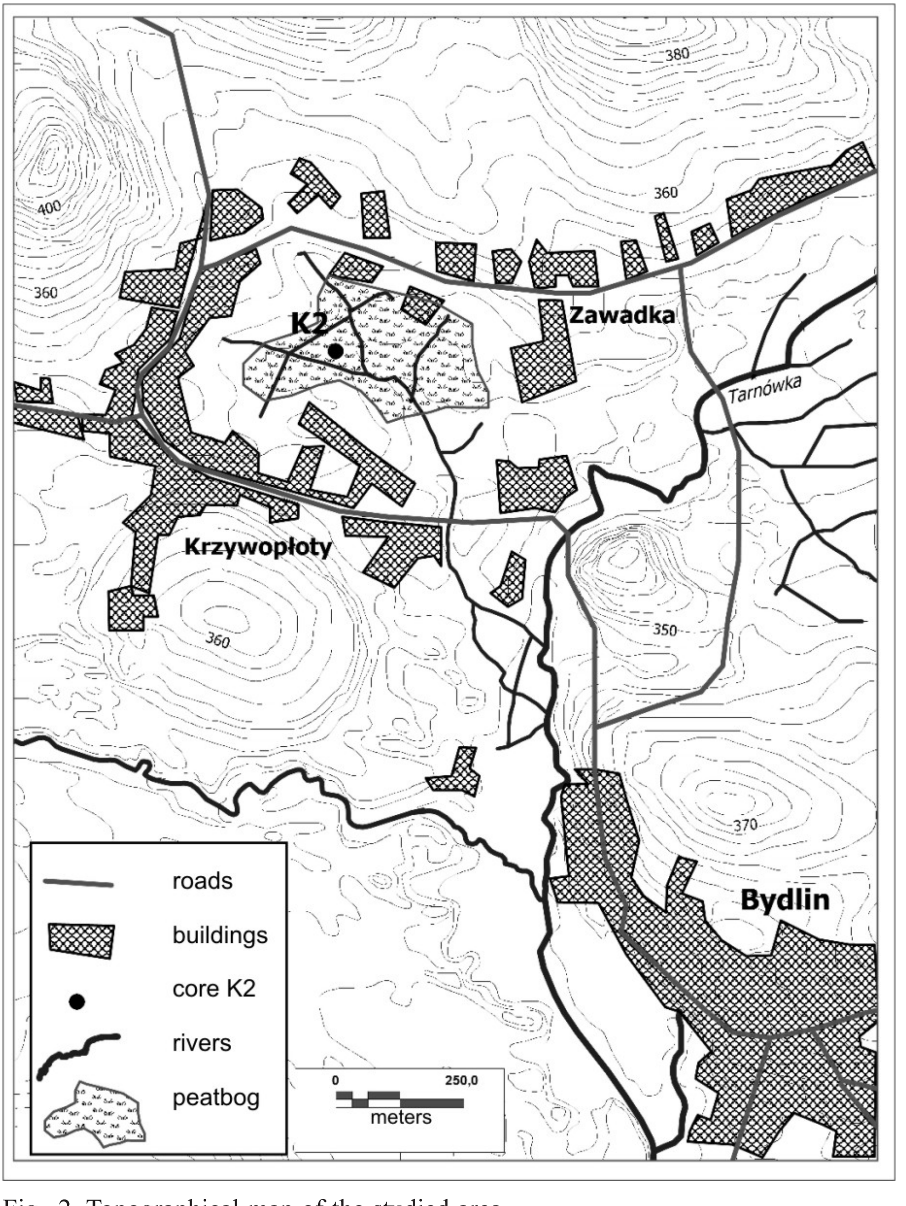

Fig. 2. Topographical map of the studied area

Methodology

Core (K2) was obtained with the use of an Instorf sounder. The sediment extracted for analysis comprised gyttjas and peats. The study focused on determining their organic matter content (P-loss on ignition), calcium carbonate content, and degree of peat decomposition (H) and pH (Tab. 1). The fresh sample was dried in air, then at 105°C and dried to a constant weight. A sample was ignited on a crucible for two hours at 550°C in a muffle furnace, then cooled to room temperature before the weight of the sample was determined. Loss on ignition was calculated. Calcium carbonate was determined by Scheibler's method. 34 samples (each 1 cm^3 in volume) from a depth of 0.65–3.75 m were examed by means of pollen analysis. In sediments lying below a depth of 3.76–4.0 m, pollen was not recorded or the frequency was extremely low. The sampling intervals were 5–20 cm. The sediments were subjected to maceration with 10% KOH, 15% HCl, $ZnCl_2$ and Erdtman's acetolysis. Two *Lycopodium* indicator tablets were added to each sample prior to maceration.

A pollen diagram was drawn using the POLPAL computer program (Walanus, Nalepka 1999). Calculation was based on the total of trees and bushes (AP) and also herbaceous plants and draft shrubs (NAP).

Tab. 1. Description of sediment (field and laboratory) Krzywopłoty peatland

Depth [cm]	Sediment description	H [%]	P [%]	pH
0–10	slightly mucky peat		23.8	5.2
10–35	sedge–mossy peat with thick rhizomes of reed	30	13.0	6.0
35–55	sedge peat with reed and wood at the bottom	50	12.4	5.8
55–100	sedge peat with reed and fragments of wood (65–67 cm, 84–87 cm)	40, 55 at the bottom	11.5–15.9	5.6–5.7
100–162	reed–sedge peat, wood at the bottom	50	17.0–14.9	5.9–5.7
162–200	sedge–moss peat	30	15.2–10,8	5.5
200–250	sedge–moss peat	25	11.3–10.6	5.8–5.5

Tab. 1. cont.

250–300	sedge–mossy peat with fragments of wood (275–290 cm)	30	9.8	5.8–5.5
300–320	sedge–moss peat	30	12.1	5.6
320–350	bryales moss peat	10–30	15.2	5.9
350–365	sedge–moss peat	30		
365–367	peat with slightly traces of gyttja			
367–370	coarse detritus gyttja, brown		11.6	5.7
375–392	calcareous gyttja, greenish–yellow, $CaCO_3$–90%		91.9	7.1
392–412	calcareous gyttja, dark–greenish with numerous shells, the sand layer at the bottom			

Explanations: H – degree of peat decomposition [%], P – loss on ignition [%], pH – reaction

Results

The development phases of the Krzywopłoty mire

The thinness of lacustrine sediments in the Krzywopłoty profile suggests that the lake was subject to intense overgrowing processes and quickly turned into a bog. Based on the macroscopic description of the mire, the degree of decomposition, loss on ignition analysis, and pH and $CaCO_3$ levels (Tab.1), we can distinguish four phases in the development of the Krzywopłoty peatland:

Phase I (412–367 cm), lake: calcareous gyttja with a very high calcium carbonate content was being deposited. At first the water body was shallow and calcareous gyttja and an extremely large numbers of molluscs were living there, then the reservoir deepened and it became shallow again, and at the top of the lake sediments a layer of coarse detritus gyttja was formed from floating and submerged vegetation.

Phase II (367–162 cm), sedge–moss fen peat: the lake became covered with peat from floating mats of predominantly sedge–moss, with patches of bryales moss. A poorly decomposed peat, with a loss on ignition of

15–9% and acidity of 5.5–5.9, was deposited. The ground-water level was consistently high, and close to the surface.

Phase III (162–35 cm), changes in the peatland: the sedge-moss fen was replaced by a tall-sedge swamp with reeds. As a result of fluctuations in the water level, and periodic lowering, a shrub (probably osier) invaded its descent. Due to changes in the water level, a tall-sedge swamp with reeds and osier was created. The degree of decomposition of peat increased significantly (up to 50%).

Phase IV (35–0 cm), sedge moss fen peat returns: Surface water flood gave way, and put off a poorly decomposed peat. The changes in the top of the bed (mucking) are associated with peat drainage in recent decades. This is also connected with the arrival of reed, which exceeds the upper layer of peat.

Pollen analysis

Pollen stratigraphy

The pollen diagram has been divided into 7 local pollen assemblage zones—L PAZ (Tab. 2, Fig. 3) according to Birks (1986) and Janczyk-Kopikowa (1987). Chronozones were distinguished on the basis of the convention proposed by Mangerud et al. (1974).

Tab. 2. Description of the local pollen assemblage zones from the Krzywopłoty site

Depth [m]	Name of L PAZ	Description of local pollen assemblage zones (L PAZ)
0.65– –0.83	K2-7 *Pinus-Picea-Abies*	High AP values (96%). Slight increase in *Abies alba* pollen (5%). Low values of *Carpinus betulus* (3%) and *Fagus sylvatica* (1%). Fall of *Alnus* (14%) and *Corylus avellana* pollen (3%). Lack of the upper boundary.
0.83– –1.05	K2-6 *Carpinus-Abies-Alnus*	Still high pollen values of *Alnus* (38%). Low values of *Abies alba* (2%), *Carpinus betulus* (3%) and *Fagus sylvatica* (0.4%).
1.05– –1.55	K2-5 *Tilia-Alnus-Picea*	Distinct increase in *Tilia cordata* type (10%), *Alnus* (26%) and *Picea abies* (13%).

Tab. 2. cont.

1.55– –1.90	K2-4 *Corylus-Tilia-Quercus*	Decrease in *Pinus sylvestris* type (53%). Rise in *Corylus avellana* (max. 18%), *Ulmus* (max. 7%), *Tilia cordata* type (max. 4%), *Quercus* (max. 4%) and *Alnus* (max. 3%).
1.90– –2.25	K2-3 *Pinus-Ulmus-Corylus*	High values of *Pinus sylvestris* type (77%), increase in *Corylus avellana* pollen (max. 4%).
2.25– –3.45	K2-2 *Pinus*-NAP	AP 62–95%. Increase in *Pinus sylvestris* type to 83% and *Ulmus* to 6%.
3.45– –3.75	K2-1 NAP-*Betula*	High representation of herbaceous plant pollen (NAP), max. 39%. Increase in *Pinus sylvestris* t. pollen to 44% and decrease in *Betula alba* type to 17%. Lack of the lower boundary.

The boundary between the Vistulian and Holocene and the boundaries between successive chronozones were established based on their correlation with the exactly-dated profile of nearby Wolbrom (Latałowa 1989).

Development of vegetation in the Krzywopłoty area

The vegetation history recorded in organic sediments covers the period from the youngest Vistulian (YD) to the younger Holocene (SB). The pollen picture of sediments taken from the oldest part of the palynologically documented profile records the growth of the pollen share of *Pinus sylvestris* t. to 44% and the decline of *Betula alba* t. to 17% (NAP-*Betula* L PAZ, fig. 3). The forests growing in the region of the site were not dense, but probably only consisted of patches of pine and birch communities. The high proportion of NAP (max. 39%) clearly indicates that open communities of herbaceous plants still occupied large areas. The slightly higher share of NAP recorded in Krzywopłoty than in Wolbrom (Latałowa, Nalepka 1987), Jezioro (Nita, Szymczyk 2010), or Jaworzno-Jęzor (Szczepanek, Stachowicz-Rybka 2004) is due to the relatively large share of Cyperaceae pollen. In the Younger Dryas the lake gradually disappeared and transformed into peatland. This change is documented by the transition from gyttja to peat sediment at a depth of 3.65 m in the lithological profile (Fig. 3).

The continuous curve of pollen *Betula nana* t. (max. 1%) suggests that dwarf birch still surrounded the site. Juniper grew in the dry habitats: its pollen values in excess of 1% are rather low compared to those of the Younger Dryas, but are typical of the Silesia-Cracow Upland (Okuniewska-Nowaczyk et al. 2004).

The composition of pollen spectra in the Preboreal chronozone indicates that the forest landscape in the vicinity of the peatland was typical for the oldest part of the Holocene. Pine forests with a very small admixture of birch dominated in the Krzywopłoty area (*Pinus*-NAP L PAZ). Later, the importance of *Betula* slightly increased (up to 21%), but the role of birches in forest communities remained small. Similarly, the low proportion of *Betula* pollen is recorded in nearby Wolbrom (Latałowa, Nalepka 1987). Much more important was the position of birch in the area of Jezioro (Nita, Szymczyk 2010), because the tree pollen values rise to 47% from nowhere. Such high values are not a typical feature of pollen spectra in this part of Poland (Ralska-Jasiewiczowa et al. 2004). In comparison with the Younger Dryas, forests were more dense. However, even fairly high values of NAP (especially Poaceae and *Artemisia*), and a large diversity of herbaceous taxa, may suggest that open communities survived in the mire surroundings in the earlier part of the *Pinus*-NAP zone. Fairly high values of Cyperaceae pollen (up to 30%) can also be associated with the development of the peatland. Although in the younger part of the Preboreal chronozone *Ulmus* and *Corylus avellana* appeared and later *(Pinus-Ulmus-Corylus* L PAZ), a dominant role in the forest landscape to the end of this period was served by *Pinus*. Hazel probably invaded more fertile habitats within the pine forests, but very low values of its pollen (max. 4%) indicate a sporadic occurrence. Only at the turn of the Preboreal / Boreal chronozones were forest landscape beginning gradually to diversify.

A characteristic feature of the Boreal chronozone (BO) is the increased importance of *Corylus avellana*. Hazel pollen values in the Krzywopłoty profile (max. 18%) are slightly higher than those measured in nearby Wolbrom (Latałowa, Nalepka 1987, Latałowa 1989), and slightly higher than the average values recorded for this region of Poland (Miotk-Szpiganowicz et al. 2004). The *Ulmus* pollen values listed in the test profile (max. 7%) can also be considered high for this region (Zachowicz et al 2004). Oak (*Quercus*) was a new component of the forest, and probably invaded the pine communities. Linden (*Tilia cordata* t.) was present, and alder (*Alnus*) grew in wet habitats. However, the very low values of pollen from these trees suggest that they occurred only as a small addition. Despite a constant downward trend, pine was still the main component of forest communities. Only in the Atlantic chronozone did the forest composition change radically into mixed deciduous forests, with the oak, linden, maple and hazel which were typical for this period. Noteworthy are the high values of *Tilia cordata* t. pollen (max. 10%) compared to average values for this region (Kupryjanowicz et al 2004) and listed in nearby sites. An example is the Jezioro profile, where the proportion of linden pollen does not exceed 4% (Nita, Szymczyk 2010), while slightly higher values occur in the Wolbrom site (Latałowa 1989). The alder communities mixed with ash (*Fraxinus excelsior*) were also spreading. There was also an increase in the importance of spruce (*Picea abies*). Low *Pinus sylvestris* t. pollen values suggest that the role of pine was already low at that time.

At around the border of the AT and SB chronozones, there is a noticeable decrease in the pollen of *Ulmus*, *Corylus avellana* and *Tilia cordata* t. The profile of palynologically documented sediment ends with sediments correlated to the older part of the Subboreal chronozone. Here, a new but not very common component of forests was *Carpinus betulus*, *Fagus sylvatica* and *Abies alba*. The role of pine was again of greater importance. However, the specific local feature is the increasing importance of alder in the oldest part of the Subborel chronozone, probably associated with hydrological changes in the surrounding of the peatland.

In the Krzywopłoty profile there are a few indicators of human agricultural activities, which are represented by single pollen grains of *Triticum* t., *Cerealia* t. and *Plantago lanceolata*. However, the very high share of the AP suggests no trace of deforestation as it indicates that the peatland was surrounded by very dense forests.

Conclusion

The comparison of the geological analysis of Krzywopłoty peatland deposits to palynological analysis allowed us to trace developments in the sediments of the reservoir. Although for the Krzywopłoty profile the ^{14}C method was used to date sediments from a depth of 4.45–4.50 m, the radiocarbon date obtained (4450 ± 70 BP) proved to be completely incompatible with the results of pollen analysis. The pollen spectra of sediment, which are much higher in the lithological profile, at a depth 3.45–3.75 m, point clearly to the end of the Late Glacial (YD).

In the Late Glacial, probably in Allerød and in the Younger Dryas, the lake reservoir was formed in a depression amply filled with water saturated with calcium carbonate. Limestone gyttja accumulated in it, and the lake gradually deepened. After the shallowness of the water body with limestone deposits, the final stage of the existence of the lake (during the Younger Dryas) saw floating and submerged vegetation result in the accumulation of a thin layer of detritus gyttja.

In the Eoholocen (PB and BO) there was a sedge moss fen peat, initially surrounded by communities of pine trees, and later of pine, hazel and elm. In the Atlantic and Subboreal period there was a clear change in succession. The sedge moss fen peat was replaced by sedge swamp with reeds, periodically covered with bushes. During floods the peatland was covered with water to create reservoirs which gradually disappeared due to evaporation and outflow. The pine forests gave way to multispecies communities of linden, oak, elm, maple and hazel, which are characteristic for the Atlantic chronozone, and later, in the Subboreal chronozone, with an admixture of hornbeam and fir. Flooding of the peatland has ceased over the last few hundred years and sedge-moss vegetation have returned.

The Krzywopłoty peatland succession cycle is similar to cycles described in detail (Żurek 1975, Oświt, Żurek 1981) in some parts of the The Biebrza Valley. In the Biebrza ice-marginal valley in the Late Glacial and Old Holocene, calcareous, and later detritus, gyttjas accumulated. During the Boreal and Atlantic phase gyttjas were being covered by sedge-moss peat. In the Subboreal and Subatlantic phases the reed and sedge peats stretch over the whole flood terrace.

Pollen succession shows a great similarity in succession to nearby Wolbrom (Latałowa and Nalepka 1987, Latałowa 1989).

Acknowledgements

The authors would like to thank Norbert Woźniak for field work and Iwona Wolińska, who performed laboratory analysis of loss on ignition, pH and calcium carbonate in the Laboratory of the Institute of Geography UJK in Kielce.

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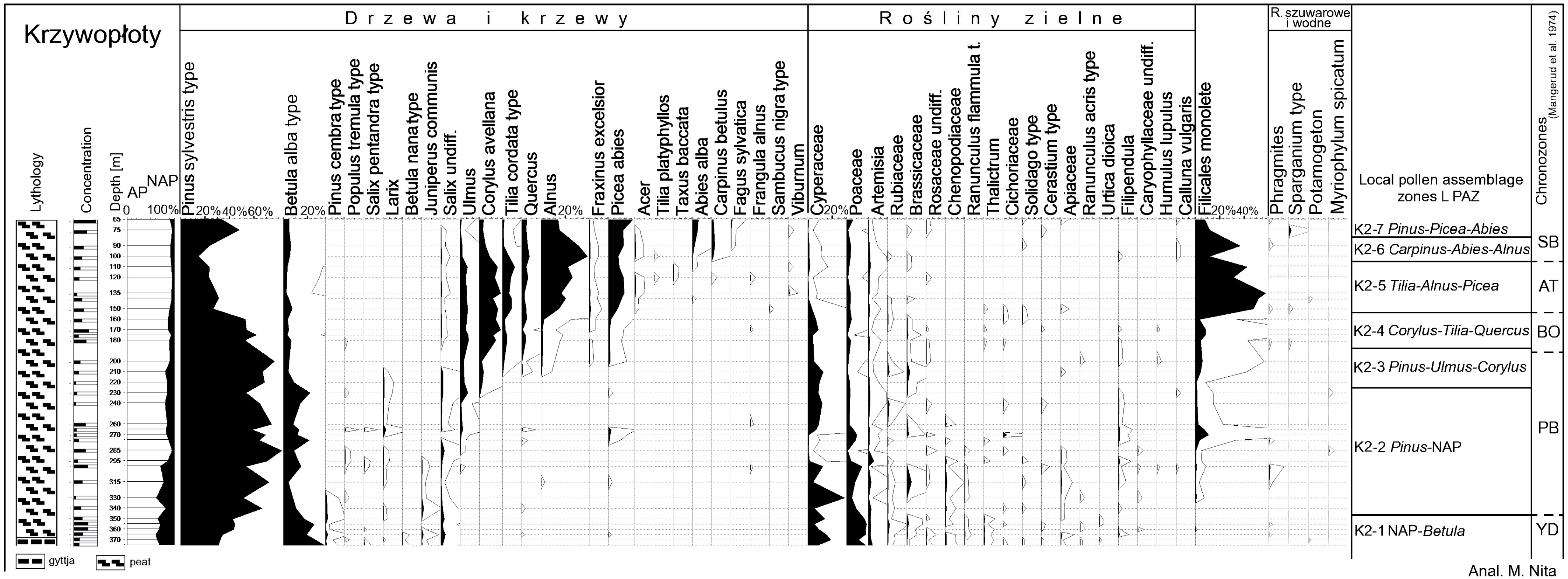

Fig. 3. Simplified pollen diagram from the Krzywopłoty site